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RESEARCH PAPER

Measuring leaf necrosis and chlorosis of bamboo induced by typhoon 0613 with RGB image analysis

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Abstract: Symptoms of leaf necrosis or chlorosis of bamboo induced by Typhoon 0613 (T0613) were analyzed using RGB image analysis in Yamaguchi city, Japan. Results showed a closely positive relationship between Green/Red (G/R) value for indoor taking images of bamboo individual leaves and chlorophyll meter value (SPAD) with regression coefficient of 0.961. The relation between G/R value of room taking images and Necrotic Area Percentage (NAP) for bamboo individual leaves showed an inverse logistic function relationship, with the correlated coefficient equaling to 0.958. Both leaf chlorosis and necrosis can be quantitatively estimated by RGB image analysis. Moreover, the variance of Green/Luminance (G/L) value for the same leaf was less than that of G/R for images taken in the conditions with large light difference, especially for green leaves. G/L value also exhibited a closer relationship with SPAD value of leaves with chlorosis than that of G/R values at the same condition. The relationship between G/L value for bamboo canopies and the Distance from Coastline (DC) was also closer than that of the G/R value for the images taken at field sites with big light difference.

Keyword: bamboo; G/R value; G/L value; leaf necrosis and chlorosis; less rainfall; T0613

Introduction

As response to unfavorably extreme environmental stresses such as salt damage, water stress, hot injury, nutrition deficiency, excessive pesticide etc, which is also called physiopath (Treshow 1970), many plants show symptoms of leaf necrosis or chlorosis at leaf tip and margin even overall leaf. Salisbury (1805) noted that strong typhoon without rainfall often resulted in great leaf injury. The typhoon with less rainfall in Yamaguchi revealed that the leaf necrosis and chlorosis induced by Typhoon 0613 (T0613) occurred as Salisbury's note. Following the T0613's hit, leaf necrosis has appeared on many trees and shrubs in Yamaguchi city, especially on bamboo leaves. Leaves on the same crown or canopy presented not only chlorosis but also necrosis for a period of time.

As an important approach, image color system analysis, especially RGB image analysis, and the concerned applications in measuring plant chlorophyll, nitrogen and disease status have been well reported (Kawashima et al. 1998; Xu et al. 2002; Okado et al. 1993; Suzuki et al. 1995; Lei 2004). In the research of wheat and rye, Kawashima et al. (1998) considered the normalized difference (red-blue)/(red+blue) was the most applicable function using data collected under different meteorological conditions by portable video camera. Iwaya et al. (2005) measured water content of wheat panicle by (R-G)/(R+G) value etc. Suzuki et al. (1999) used the G/(R+G+B) for broccoli identification. Cai et al. (2006) found that R/(R+G+B) was the best parameter for estimating leaf chlorophyll content, and G/R and R/(R+G+B) for estimating carotenoid content of cucumber leaf. In the research of wheat senescence, Adamsen (1999) stated that the relationships between G/R and SPAD were linear over most of the range of G/R and it responded to both chlorophyll concentrations in the leaves and the number of leaves present. The image color analysis has also been applied in the studies about nutrition deficiency of plants (Honami et al. 1992; Xu et al. 2002) and flower number detection (Adamsen 2000). Although the observation condition, objective plant material and selected optimum indices are different among the researches, almost all of them analyze the RGB image by ratio values and are focused on the color change of the plant, especially on chlorophyll evaluation of the plant canopy (Cai 2006). Almost no study has been found on the research of leaf necrosis of trees by RGB image analysis, especially on the leaf necrotic area analysis. In this paper, the RGB image analysis was used in the study not only for leaf chlorosis but also for leaf necrosis of bamboo hit by T0613 with comparing of the G/R and G/L values.

Materials and methods

The meteorological data was obtained from Automated Mete-

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orological Data Acquisition System (AMEDAS) of Japan and Hazard Protection Information System in Yamaguchi Prefecture (HPISYP). It includes the maximum wind speed, daily precipitation during the hit of T0613 and monthly precipitation in Sep. and Oct., precipitation during hit by strong typhoon (maximum wind speed over 15 m/s) and 44 day's precipitation after hit by typhoon in the past 40 years (from 1967 to 2006).

Fifty-two and 50 bamboo leaves were typically sampled from a bamboo stand in Yamaguchi University for image taking of chlorosis and necrosis, respectively. The images for RGB analysis were taken at a position of 50 cm above the sampled bamboo leaves at natural light condition with a camera (Nicon D70S) mounted on a tripod. The images were stored in the form of JPEG. The resolution of images was 300 dpi and 3000×2000 pixels. According to the known researches (Adamsen 1999; Iwaya 2005; Cai 2006) and the screening of indices in this research, the G/R and G/L values were selected for RGB image analysis. The Red (R), Green (G) and Luminance (L) values were read from the average histogram value of leaves selected by Magic Wand Tool of Photoshop. Since the parts out of the leaves are removed by hand treating, the impact of image noise can be very small by this image process method.

The images for calculation of Necrotic Area Percentage (NAP) were obtained from a Canon scanner (d125u2). NAP is the proportion of necrotic part to overall leaf area (refer to Fig. 1), which is measured by respectively getting pixels of overall leaf and the green part of it. It is calculated by Equation (1).

$$NAP = 100 - \frac{\text{pixels of green parts}}{\text{pixels of overall leaf}} \times 100 \quad (1)$$

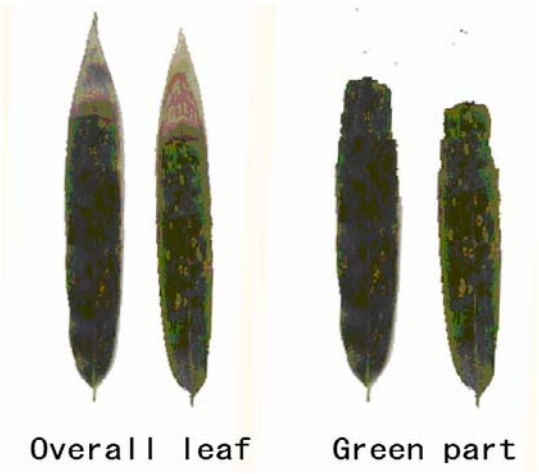

Fig. 1 Images for green part and overall individual leaves

The images for comparison of G/R value and G/L value were taken from different light conditions, both indoor and outdoor, from early morning to afternoon, with the same camera and image taking method mentioned above. The shutters of camera were respectively 1/1000, 1/50, 1/30, 1/4, 1/3 and 1 for different image taking conditions. SPAD values of individual leaves with chlorosis were impartially measured by using SPAD-502 chlorophyll meter with 30 duplications per leaf, in order to study the relationship between mean SPAD value and G/R or G/L value.

The most seriously damaged bamboo stands in each investigated area were selected from windward of mountains for the comparison of G/R and G/L. The image of bamboo canopy was taken by using a common digital camera (Canon IXY 6.0) about 30–50 m away from the bamboo stands. It is characterized by horizontally taking the image on ground level. The preparing method of image was similar to the method for images of individual leaves. The distance from coastline (DC) of every bamboo stands was measured by tool of electronic atlas by the name of E-Atlas Z Proffessional5. It was the shortest distance from stand sites to the coastline.

Results and analysis

The characteristics of T0613 and response from trees and shrubs

The T0613 was characterized with lower precipitation, higher wind speed with the maximum wind velocity 20 m/s and daily precipitation 24 mm when it passed through the Yamaguchi City. This period of rainless or less rainfall persisted for more than one month after its hit. According to the data from AMEDAS of Japan, it made a minimum precipitation record in 44 days after strong typhoon's hit, only 8.5 mm. It created a sufficient condition for landscape trees to develop symptoms of leaf necrosis or chlorosis (refer to Table 1).

Table 1. Related meteorological data for Yamaguchi.

	During Typhoon 0613	Past 40 years Max	Mean	Min
Max. gusty wind (m/s)	42.4	53.1#	39.5#	33.2#
Max. wind speed (m/s)	20.0	28.8*	21.0*	15.4*
Precipitation in the day typhoon hit (mm)	24.0	247.0*	91.2*	5.0*
Precipitation in 44 days after typhoon hit (mm)	8.5	544*	233.1*	8.5*

* The data came from typhoon's hit that maximum wind speed was over 15 m/s, and the maximum gusty wind speed was over 33 m/s.

Strong typhoon is one kind of disaster that can make seriously mechanical damage to trees and shrubs, such as stem breaking, uprooting, bending and slanting and so on. During the hit by T0613, although such kind of damage less occurred, it did injury many landscape trees and induced leaf necrosis or chlorosis at the tip and margin of trees in Yamaguchi city, such as Metasequoia *(Metasequoia glyptostroboides*), Ginkgo (*Ginkgo biloba.)*, Trident maple (*Acer Buergerianum*), Blue Japanese Oak (*Quercus glauca*) and Camphor tree (*Cinnamomum camphora*), etc. It made the crown of some landscape trees significant difference between windward and leeward, and the injured crowns even can be clearly divided into green part and non-green part (refers to Fig. 2). Leaves in the bamboo stands were discolored after hit by T0613.

Measuring leaf chlorosis and necrosis by image G/R values for individual bamboo leaves

Based on the mechanism of SPAD value measurement, it is a sensitive method to the chlorophyll of plant leaves, especially the paddy rice etc. But one measuring data of SPAD value measured by SPAD-502 only responds to the leaf chlorophyll status of 6 mm^2. To perfectly respond the chlorophyll status of overall leaf, a large number of random measurements must be taken to reduce variability and make statistical data comparable. In the study, one sampled leaf was measured with 30 duplications, which was the maximum memory number of SPAD-502 chlorophyll meter. Therefore, it should be the proper estimating value of the chlorophyll status of sampled leaves. However, the G/R value from RGB image analysis in this research was characterized by measuring the overall leaf fast and easily. Fig. 3 shows a positive linear relationship between G/R value and SPAD value, with R^2 = 0.961. The G/R value ranges from 0.7 to 1.3 and the SPAD value from near 0 to 43. The related function is Y= –64.14 + 83.578X. Higher relationship between SPAD value and G/R value of RGB image implies that the G/R value of bamboo individual leaves can be recognized as a way responding to leaf chlorosis status.

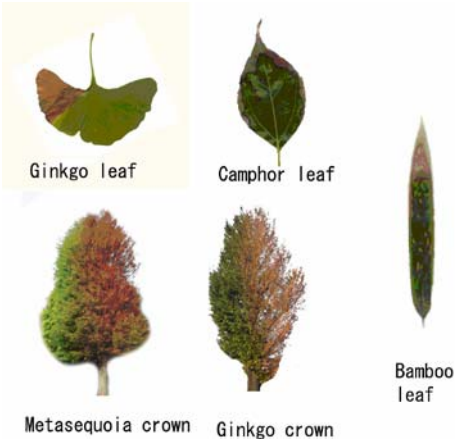

Fig. 2 Necrotic leaves and damaged crown induced by T0613

In the research, the NAP was considered as the criterion of necrosis status of individual leaves. The relation between G/R value and NAP of bamboo leaves showed an inverse logistic relationships, with function Y= 100 / (1 + 3.323785E-12 $e^{21.65X}$), R^2 = 0.958 (refer to Fig. 4). It means that as the NAP increases the G/R value deceases smoothly, then sharply, and then becomes stable. The relation function seems that the G/R values of leaves with the same NAP of 0% or 100% are not unique. After removing the leaf samples with NAP of 0% and 100%, the relation function almost changed to a linear function, Y= 386.3–362.77X (refer to Fig. 5) and the corresponding correlation coefficient R^2 = 0.8945. From this point of view, both chlorosis and necrosis can be quantitatively determined by using the G/R value of RGB image, especially the NAP, which is disable for SPAD measurement and visual estimation.

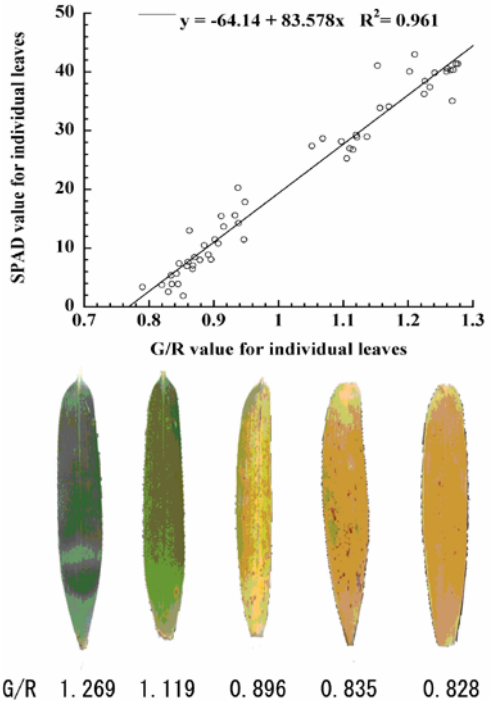

Fig. 3 Relation between SPAD and G/R for individual leaves with chlorosis, and the typical images of bamboo leaf blade with different chlorosis. In the common situations, bamboo leaves usually had small necrosis leaf tip. In order to measure the G/R or G/L value of chlorosis leaves, the leaf tip was cut off before image analysis in the research

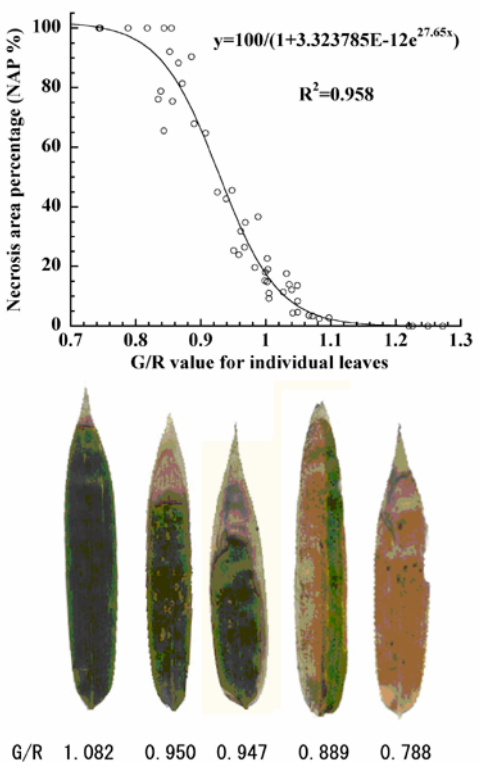

Fig. 4 Relation between G/R value and Necrotic Area Percentage (NAP) for individual leaves, and typical image of bamboo leaf blades with different necrosis

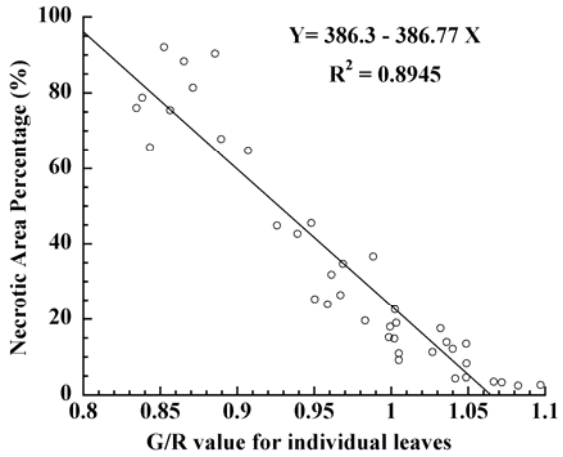

Fig. 5 Relation between G/R value and Necrotic Area Percentage (NAP) after removing the leaves with NAP equaling to 0% and 100%

The comparison of G/R value and G/L value of RGB images with big difference in luminance

Kawashima et al. (1998) have ever thought of leaf color discrimination with a portable video camera would be difficult under clear conditions with direct solar radiation. Okado et al. (1993) considered that the variance of sunlight could make a negative effect to the result of chlorophyll estimation and it could be treated by image correction. We have met the same situation and tried to reduce the effect of light condition by selecting proper indices. In lab color system, *L* value stands for "luminance", which is the linear combination of the *R, G* and *B* value from RGB color system. The relationship between *L* value and *R*, *G, B* was expressed by Equation (2):

$$L=0.299R+0.587G+0.114B \quad (2)$$

According to this relationship, the *R, G* and *B* value vary with the difference of luminance value. According to our test by taking photo image at different light environment for the same leaf, with different *L* value obtained, it appeared bigger variance of *G* and *R* value, even the G/R value especially for the green leaves. As the G/R value gets bigger, the difference also becomes larger (refer to Fig. 6A). Theoretically speaking, G/L value decreases with the increasing L value. It may be an index that can reduce the impact of luminance from photo images. The G/L value (refer to function (3)) exists a similar structural character to $G/(R+G+B)$ and $R/(R+G+B)$ as used by other researchers (Suzuki et al. 1995; Cai et al. 2006).

$$G/L = G / (0.299\mathrm{R} + 0.587G + 0.114B) \quad (3)$$

According to the comparison of G/R value and G/L value in the study, the G/L value is much closely related to the SPAD value of sampled leaves from images with big luminance difference than that of G/R value (refer to Fig. 6B; Fig. 7B). It is clear that there is a large difference of variance between G/R value and G/L value for the same sampled leaf at different photo taking conditions. The variance of G/L is about 1/12 of the G/R value and the average variance/mean (AVM) values of G/R and G/L are 10.03 and 0.798, respectively. It is evident that the variance of G/L value among the different images with big luminance difference is significantly lower than that of G/R value (refer to Fig. 6A; Fig. 7A).

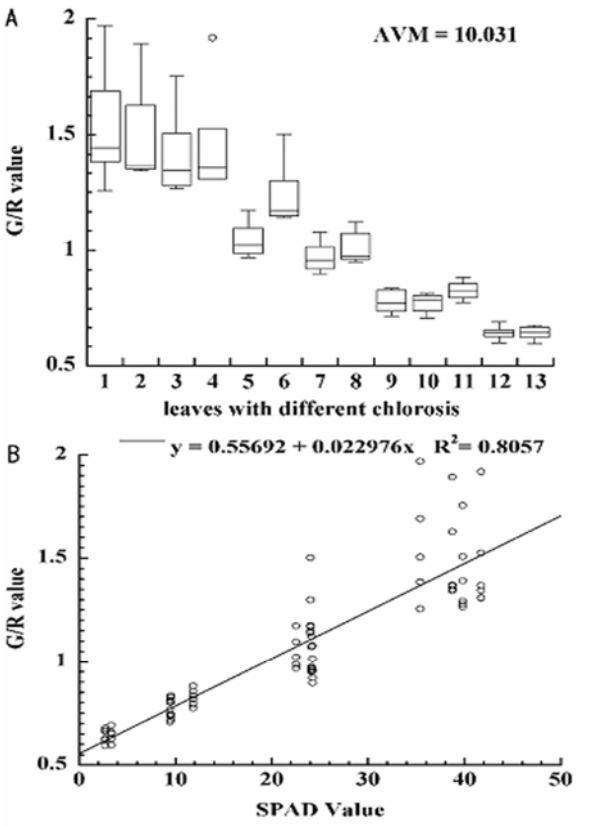

Fig. 6 The 6A is the variation of image G/R value for different leaves at different light conditions. The AVM in 6A is an average value of variance/mean; the 6B is the relationship between G/R and SPAD.

Although the G/L value is not able to improve RGB analysis result for the images token in a large different light condition to the perfectly same, it can give a nearer corrected value from different images with big difference of luminance.

By the image analysis of bamboo stands, a similar result was obtained. The relationship between G/L value for bamboo canopies and the Distance from Coastline (refer to Fig. 8A) was also much closer than that of the G/R value (refer to Fig. 8B) for the images taken at field sites with big light difference.

However, based on our research, the G/R value can be much closely related to SPAD value of leaves for the RGB image taken at the small light difference conditions, such as scatter light condition of cloudy day or indoor natural light conditions. For example, Fig. 3 showed a close relationship between G/R value and SPAD value. It was the result coming from three images taken at indoor scatter light condition. The concerned correlation coefficient for G/L value was 0.843, with regression function $Y= 0.0032x + 0.985$. At this kind of condition, G/L value maybe goes beyond the proper limits in correcting the big luminance difference.

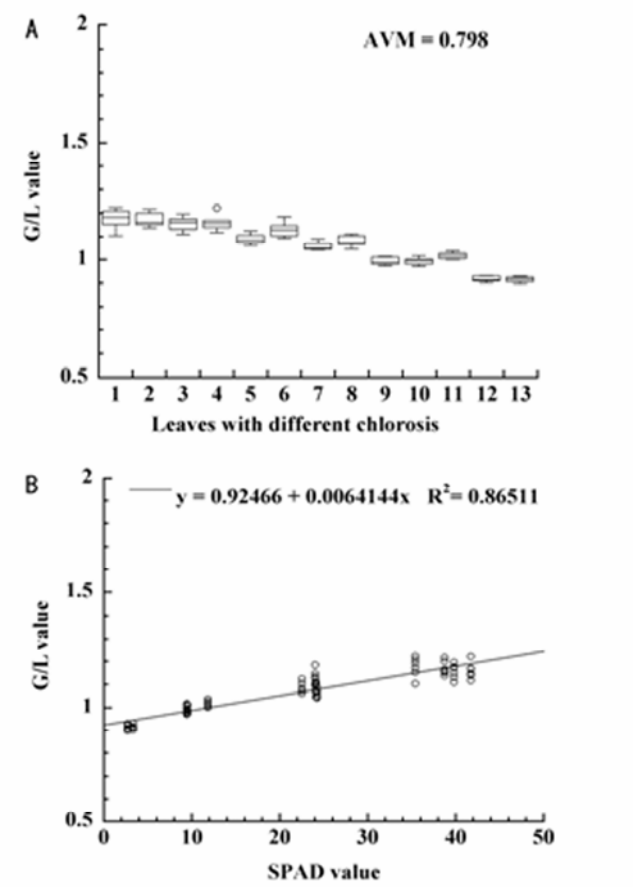

Fig. 7 The 7A is the variation of image G/L value for different leaves at different light conditions. The AVM in 7A is an average value of variance/mean. The 7B is the relationship between G/L and SPAD value for these leaves.

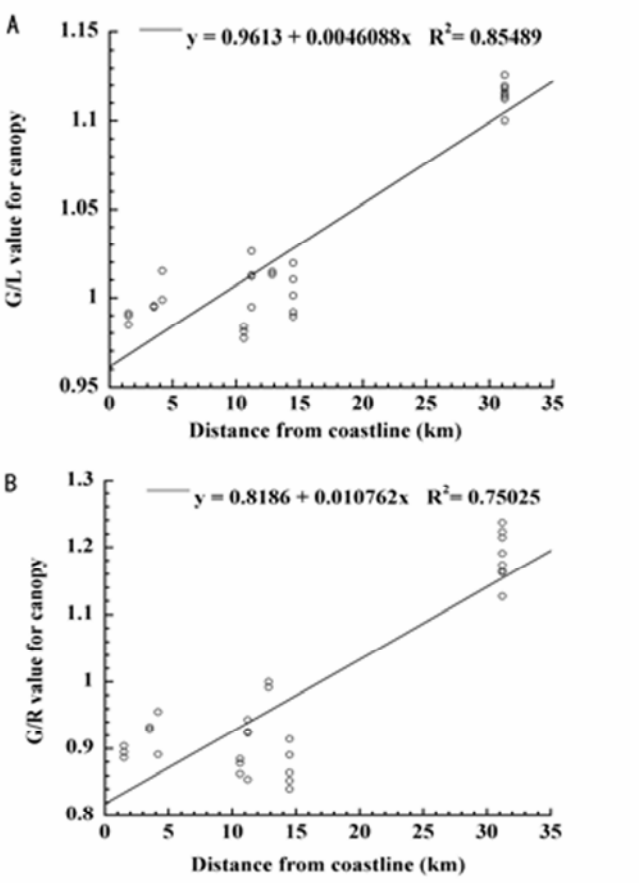

Fig. 8 The 8A is the relationship between image G/L value for bamboo canopies and the Distance from Coastline (DC); The 8B is the relationship between image G/R value for bamboo canopies and the Distance from Coastline (DC).

Conclusion

The strong typhoon without rainfall associated can result in not only mechanical damage to the trees and shrubs, but also physiological injury. The hit by T0613 with less rainfall becomes an example that made many trees and shrubs appear leaf necrosis or chlorosis at leaf tip and margin in a large area. Based on the RGB image analysis, not only chlorosis but necrosis also can be quantitatively determined by measuring image G/R or G/L value of bamboo leaves. It appears a positive linear relationship between G/R value and chlorosis of bamboo individual leaves, and a significant inverse logistic relationship between G/R value and necrosis of bamboo individual leaves for indoor taking images. It has a potential to be an alternative way to determine the vigor status of bamboo leaves damaged by typhoons like T0613.

Almost no research has been found to compare G/R value and G/L value. Based on the research, the G/L value can get a closer relation with the SPAD value of sampled leaves for the RGB image taken at conditions with bigger luminance difference, and the variance of G/L value is lower than that of G/R value, especially for green leaves. It indicates that the relationship between G/L value for bamboo canopies and the Distance from Coastline can also be much closer than that of the G/R value for the images taken at field sites with big light difference. The G/R is more suitable to be used to analyze the RGB image taken at the conditions with small light difference.

Comparing to traditional visual scale method, the RGB image analysis provides a simple and fast tool to estimate the leaf necrosis and chlorosis hit by typhoons like T0613. It will make it possible to a mass investigation in a large scale of area for its less labor need and less time consumption.

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